Modeling the Endpoint Uncertainty in Crossing-based Moving Target Selection
基于“穿越”的移动目标选择落点不确定性建模

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Crossing-based selection, by its meaning, refers to the way of selecting a target by crossing its boundary instead of pointing inside its perimeter (**Figure 1**). With the increasing popularity of novel input modalities such as pen, finger or in-air gesture, this crossing paradigm has gained increasing attention as it can adapt to these input modalities more naturally and can also improve user performance in many scenarios.

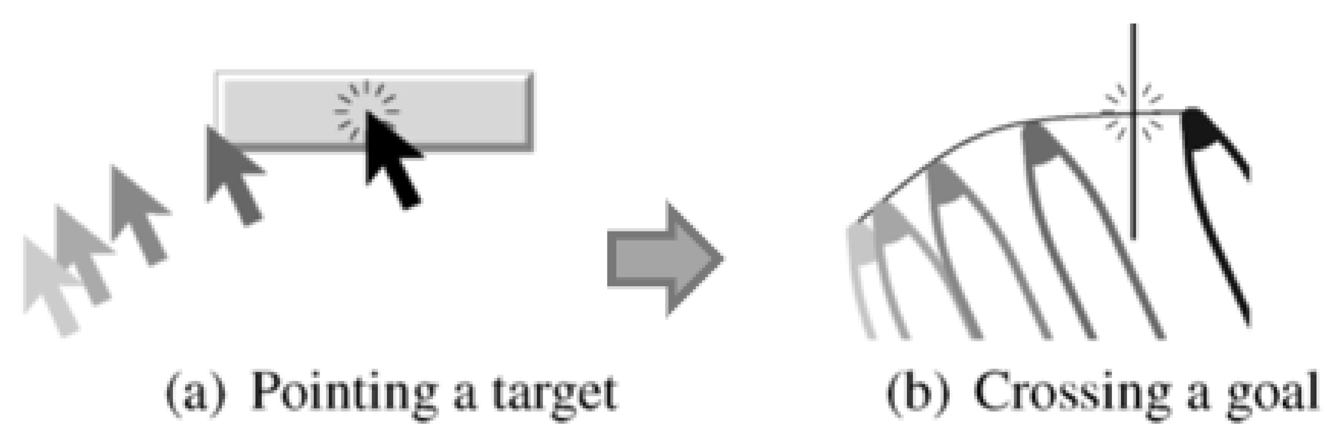


Figure 1. Tasks of target selection and crossing-based target selection

Interactive systems with dynamic contents, such as video games, augmented/virtual reality (AR/VR) systems and video surveillance applications are becoming ubiquitous nowadays. Although **moving target acquisition** with crossing has already been adopted in many applications, there is still little understanding of human performance in crossing-based moving target acquisition in the HCI literature.

The HCI team at IEL is the first team in the world to carry out the research on modelling the uncertainty of moving target selection. After discovering the ***Ternary-Gaussian* model** for understanding the uncertainty in moving target selection in 1D and 2D spaces, the research team further extends their model to the task of crossing-based moving target selection in this work (**Figure 2**).

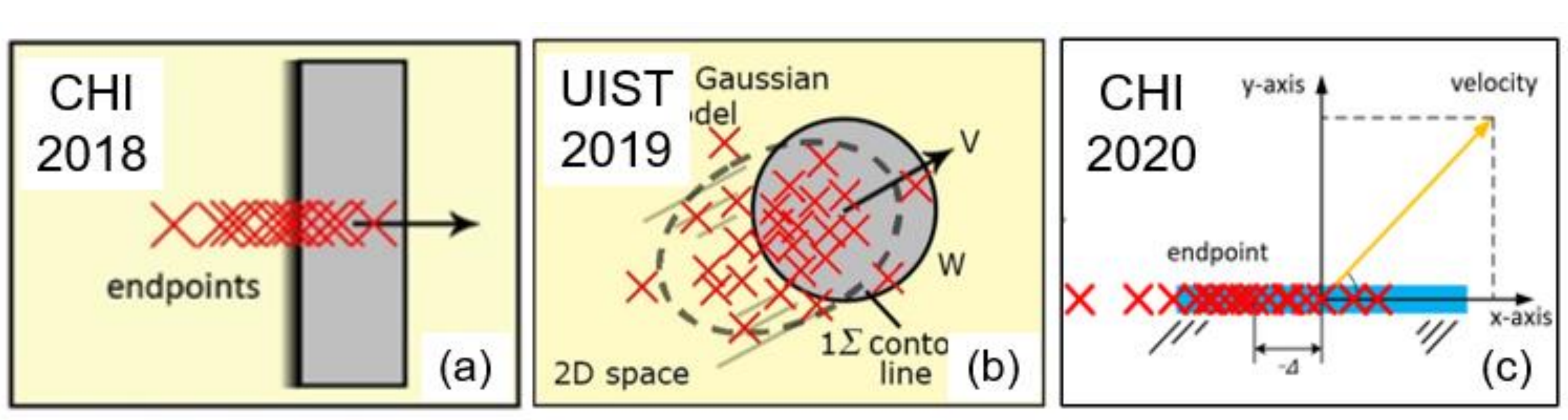


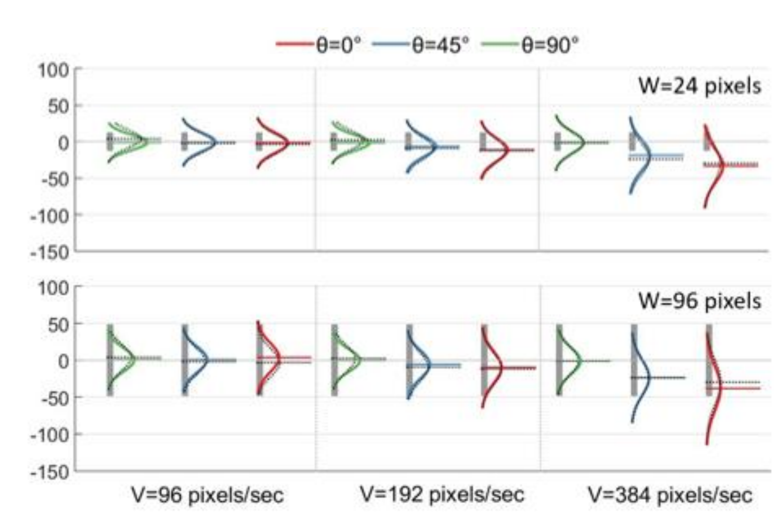
Figure 2. Modeling the uncertainty in three different tasks with the *Ternary-Gaussian* model

The *Ternary-Gaussian* model assumed the endpoint distribution consisted of three Gaussian distributions, generated from uncertainties of input device, target length and the target speed. By considering additional factors of moving direction and target orientation, the research team extended the model to crossing-based moving target selection. A new speed related Gaussian component, caused by accuracy loss of human hand in fast motion, was put into the original model to reflect the unique effects of factors in crossing selection. Therefore, the new model was named as ***Quaternary-Gaussian model***.

To validate the proposed model, the research team conducted an experiment with discrete crossing tasks on five factors, i.e., initial distance, size, speed, orientation, and moving direction (**Figure 3**).

Figure 3. The task and experimental setting

Results showed that our model fit the data of the two parameters of Gaussian distribution μ and σ accurately with adjusted R^2 of 0.883 and 0.920 (**Figure 4**).



Model	Para.	Adj. R^2
Ternary-Gaussian	μ	0.381
	σ	0.474
Quaternary-Gaussian	μ	0.883
	σ	0.920

Figure 4. The fitting performances of the *Ternary-Gaussian* and the proposed models

The research team also demonstrated the validity of the proposed model with good performances in predicting error rates in crossing-based moving target selection (**Figure 5, left**). By changing target speed and target size in a wider range of values, the research team provide an “error rate spectrum” reflecting effects of the two factors on the error rates of crossing selection (**Figure 5, right**). Based on the results, the research team concluded with implications for future designs in user interfaces with dynamic content.

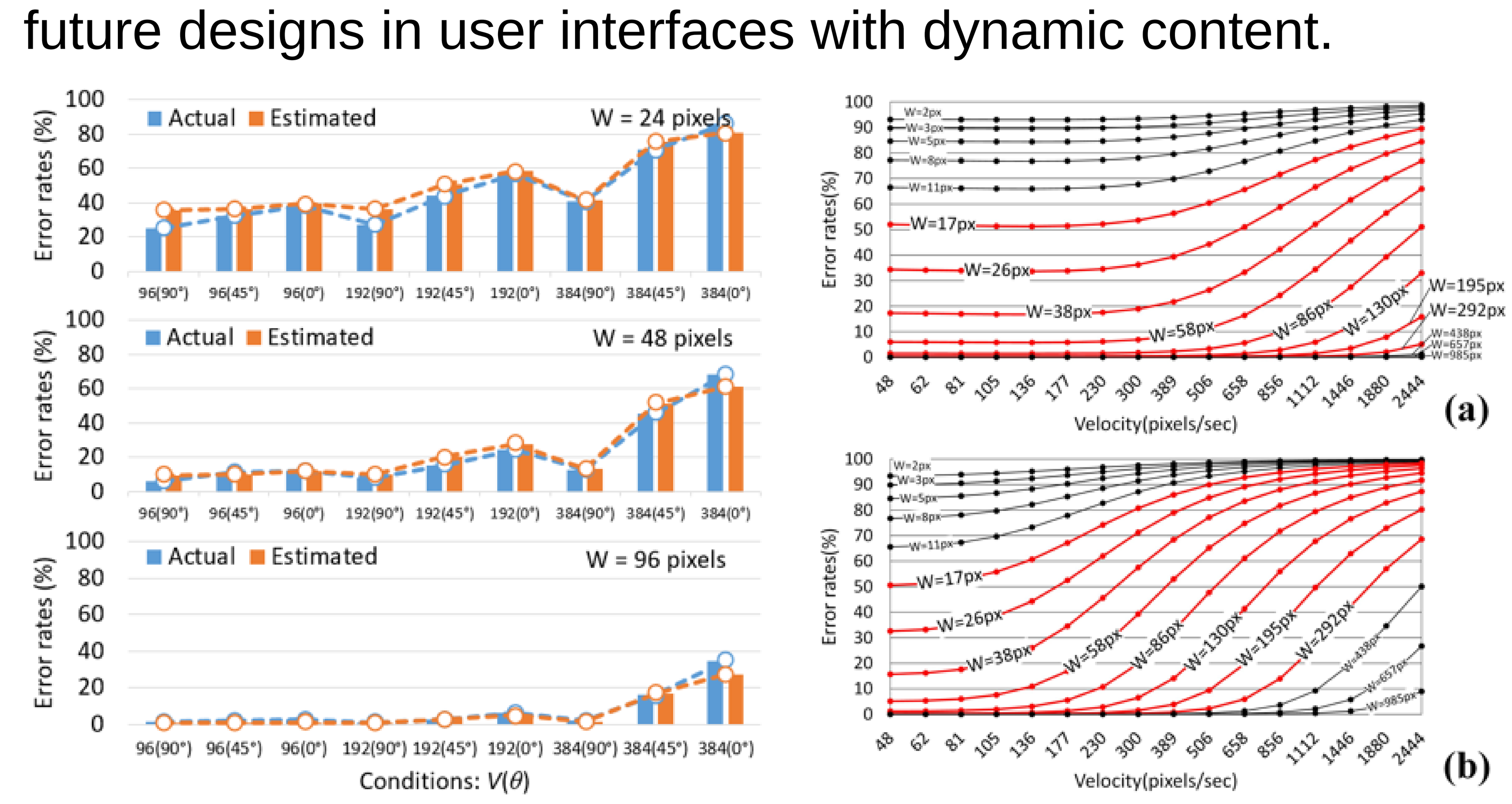


Figure 5. The estimated and actual error rates (left); Error rate spectrums (right)

This work not only demonstrates the robustness and generalizability of the *Ternary-Gaussian* model, but also **extends the research work of moving target acquisition from pointing to crossing paradigm.**